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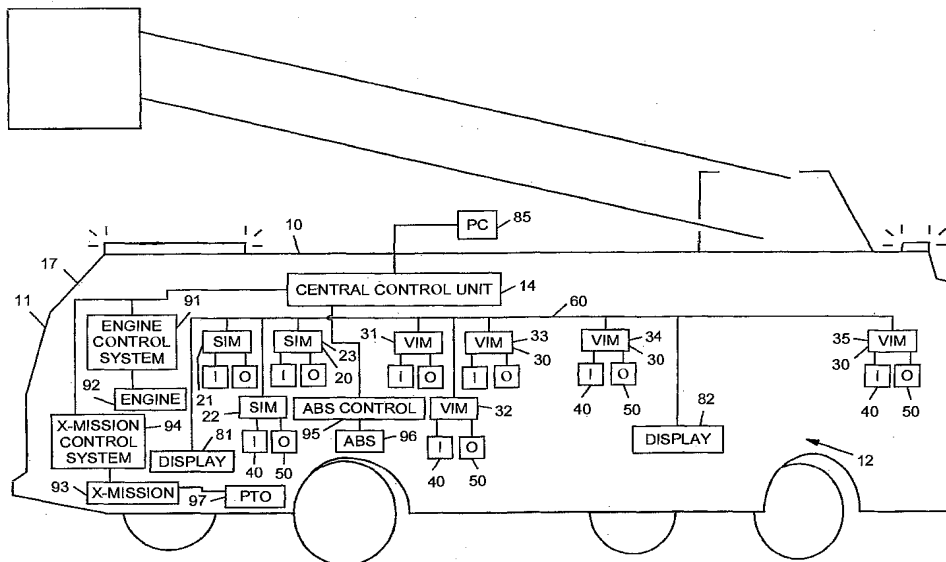
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(54) Title: TURRET POSITIONING SYSTEM AND METHOD FOR A FIRE FIGHTING VEHICLE



(57) Abstract: A turret for a vehicle includes a first gear, an apparatus, and a position sensor. The first gear is coupled to the vehicle, and is stationary relative to the vehicle. The apparatus is coupled to the vehicle and configured to rotate relative to the vehicle. The apparatus includes a second gear which is rotatably coupled to the first gear and is configured to rotate as the apparatus rotates relative to the vehicle. The position sensor is coupled to the second gear and is configured to measure the position of the apparatus.

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## **TURRET POSITIONING SYSTEM AND METHOD FOR A FIRE fighting VEHICLE**

### **CROSS REFERENCE TO RELATED APPLICATIONS**

**[0001]** This application claims priority to U.S. Prov. No. 60/469,661 filed on May 12, 2003, entitled "Turret Positioning System and Method for a Fire fighting Vehicle" and to U.S. Patent Application No. 10/668,623, filed on September 23, 2003, entitled "Turret Positioning System and Method for a Fire fighting Vehicle," both of which are expressly incorporated by reference herein.

### **FIELD OF THE INVENTION**

**[0002]** The present invention relates generally to the field of fire fighting vehicles. More specifically, the present invention relates to turret control systems and methods for fire fighting vehicles.

### **BACKGROUND**

**[0003]** Various vehicles are known for use in fire fighting. Fire fighting vehicles, including aerial platform trucks, ladder trucks, pumpers, tankers, etc., often employ a turret for dispensing fire fighting agents (e.g. water, foams, foaming agents, etc.) onto areas such as fires, chemical spills, smoldering remains of a fire, or other similar areas. Such turrets typically comprise one or more arms which are extendable, rotatable, or otherwise moveable with electric, hydraulic, or pneumatic actuator systems. While fighting a fire, the turret may be moved around in a three-dimensional space by using the actuator system to move individual arms. Once a nozzle of the turret is brought to a particular position and orientation relative to a fire, a fire fighting agent may be dispensed from the nozzle and directed at the fire.

**[0004]** Typically, this positioning and aiming of turrets is controlled by a human operator. According to one approach, the operator positions and aims the turret using a joystick which is coupled to the turret actuators. Unfortunately, in situations where the fire produces a large amount of smoke, the turret and the precise location of the fire become obscured from an operator's view. This situation is exacerbated by the fact that the tremendous flow of water or other fire fighting agent through the turret creates

forces which affect turret positioning, making it even more difficult for the operator to know the precise position of the turret. The result is that the operator is often susceptible to inadvertently causing the turret to collide with other objects, including for example the fire fighting vehicle upon which the turret is mounted. Additionally, because the operator's view of the turret nozzle as well as the fire may be severely limited, the operator's ability to control the position and orientation of the nozzle for maximum fire fighting effectiveness is also severely limited.

**[0005]** Further, existing turret systems are often cumbersome or difficult to operate. For example, turret systems typically allow the turret to be manually stored and locked into place to avoid damage during vehicle travel. However, the process of storing and locking the turret can be time consuming because the proximity of the turret to other equipment on the fire fighting vehicle requires that the turret be controlled with great care. Additionally, when the fire fighting vehicle arrives at the scene of the fire and the turret is first deployed, it is necessary for a fire fighter to manually deploy the turret from the stored position, thereby diverting the fire fighter's attention away from other important activities. Finally, the operator interface used to control the turret limits the operator's ability to control the turret from a variety of different vantage points and with the benefit of a variety of different views of the turret and the fire. A variety of other problems exist which relate to the difficulty and/or amount of operator involvement required to operate turrets.

**[0006]** Also, existing turret systems often use unreliable and/or complex systems to measure the rotary position of the turret. This problem is exacerbated by the generally large size of the turret and its relatively small range of rotation. Thus, it would be advantageous to provide an improved position sensor for a turret.

**[0007]** Accordingly, it would be desirable to provide a control system for a turret which overcomes one or more of the above-mentioned problems. Advantageously, such a control system would enhance fire fighter safety by increasing fire fighting effectiveness. The techniques below extend to those embodiments which fall within the scope of the appended claims, regardless of whether they provide any of the above-mentioned advantageous features.

## SUMMARY

[0008] According to an exemplary embodiment, a turret for a vehicle includes a first gear, an apparatus, and a position sensor. The first gear is coupled to the vehicle, and is stationary relative to the vehicle. The apparatus is coupled to the vehicle and configured to rotate relative to the vehicle. The apparatus includes a second gear which is rotatably coupled to the first gear and is configured to rotate as the apparatus rotates relative to the vehicle. The position sensor is coupled to the second gear and is configured to measure the position of the apparatus.

[0009] According to another exemplary embodiment, a fire fighting vehicle includes a first gear, an apparatus, and a position sensor. The first gear is fixedly mounted to the vehicle. The apparatus is coupled to the vehicle and configured to rotate relative to the vehicle. The apparatus includes a second gear which is rotatably coupled to the first gear and is configured to rotate as the apparatus rotates relative to the base. The position sensor is coupled to the second gear, the position sensor being configured to measure the position of the apparatus.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 is a schematic view of a fire truck having a control system according to one embodiment of the present invention;

[0011] Fig. 2 is a schematic view of an aerial device having a control system according to another embodiment of the present invention;

[0012] Fig. 3 is a schematic view of a vehicle having a control system according to another embodiment of the present invention;

[0013] Figs. 4-5 are block diagrams of the control system of Fig. 3 showing selected aspects of the control system in greater detail;

[0014] Fig. 6 is a diagram showing the memory contents of an exemplary interface module in greater detail;

[0015] Fig. 7 is a block diagram of a fire fighting control system capable of controlling a turret;

[0016] Fig. 8 is a schematic representation of a turret;

[0017] Fig. 9 is a block diagram of turret I/O devices connected to interface modules in the control system of Fig. 7;

[0018] Fig. 10 is a block diagram showing selected aspects functions of the control system of Fig. 7 in greater detail;

[0019] Fig. 11 is a bottom perspective view of a turret mounting assembly according to an exemplary embodiment.

[0020] Fig. 12 is a top perspective view of the turret mounting assembly from Fig. 11 according to another exemplary embodiment.

#### DETAILED DESCRIPTION

[0021] This patent application discloses various embodiments of a control system architecture in connection with fire trucks and other types of equipment service vehicles. The turret control systems and methods disclosed herein may be implemented using a stand-alone control system or using one of the control system architecture embodiments described herein.

[0022] Referring to Fig. 1, a fire truck 10 having a control system 12 is illustrated. / By way of overview, the control system 12 comprises a central control unit 14, a plurality of microprocessor-based interface modules 20 and 30, a plurality of input devices 40 and a plurality of output devices 50. The central control unit 14 and the interface modules 20 and 30 are connected to each other by a communication network 60.

[0023] More specifically, the central control unit 14 is a microprocessor-based device and includes a microprocessor that executes a control program stored in memory of the central control unit 14. In general, the control unit 14 executes the program to collect and store input status information from the input devices 40, and to control the output devices 50 based on the collected status information. The control program may implement such features as an interlock system, a load manager, and a load sequencer. As described below, the central control unit 14 is preferably not connected to the I/O devices 40 and 50 directly but rather only indirectly by way of the interface modules 20 and 30, thereby enabling distributed data collection and power distribution. The I/O

devices 40 and 50 are located on a chassis 11 of the fire truck 10, which includes both the body and the underbody of the fire truck 10.

[0024] In the illustrated embodiment, two different types of interface modules are used. The interface modules 20 interface mainly with switches and low power indicators, such as LEDs that are integrally fabricated with a particular switch and that are used to provide visual feedback to an operator regarding the state of the particular switch. For this reason, the interface modules 20 are sometimes referred to herein as "SIMs" ("switch interface modules"). Herein, the reference numeral "20" is used to refer to the interface modules 20 collectively, whereas the reference numerals 21, 22 and 23 are used to refer to specific ones of the interface modules 20.

[0025] The interface modules 30 interface with the remaining I/O devices 40 and 50 on the vehicle that do not interface to the interface modules 20, and therefore are sometimes referred to herein as "VIMs" ("vehicle interface modules"). The interface modules 30 are distinguishable from the interface modules 20 mainly in that the interface modules 30 are capable of handling both analog and digital inputs and outputs, and in that they are capable of providing more output power to drive devices such as gauges, valves, solenoids, vehicle lighting and so on. The analog outputs may be true analog outputs or they may be pulse width modulation outputs that are used to emulate analog outputs. Herein, the reference numeral "30" is used to refer to the interface modules 30 collectively, whereas the reference numerals 31, 32, 33, 34 and 35 are used to refer to specific ones of the interface modules 30.

[0026] Figure 1 shows an approximate distribution of the interface modules 20 and 30 throughout the fire truck 10. In general, in order to minimize wiring, the interface modules 20 and 30 are placed so as to be located as closely as possible to the input devices 40 from which input status information is received and the output devices 50 that are controlled. As shown in Fig. 1, there is a large concentration of interface modules 20 and 30 near the front of the fire truck 10, with an additional interface module 34 at mid-length of the fire truck 10 and another interface module 35 at the rear of the fire truck 10. The large concentration of interface modules 20 and 30 at the front of the fire truck 10 is caused by the large number of switches (including those with integral LED feedback output devices) located in a cab of the fire truck 10, as well as the large number of other output devices (gauges, lighting) which tend to be located in the cab or otherwise near the front of the fire truck 10. The interface module 34 that is

located in the middle of the truck is used in connection with I/O devices 40 and 50 that are located at the fire truck pump panel (i.e., the operator panel that has I/O devices for operator control of the fire truck's pump system). The interface module 35 that is located at the rear of the fire truck 10 is used in connection with lighting and other equipment at the rear of the fire truck 10.

[0027] In a preferred embodiment, the interface modules 20 and 30 receive power from a power source by way of a power transmission link. The power transmission link may comprise for example a single power line that is routed throughout the fire truck 10 to each of the interface modules 20 and 30. The interface modules then distribute the power to the output devices 50.

[0028] It is therefore seen from Figure 1 that the relative distribution of the interface modules 20 and 30 throughout the fire truck 10 in combination with the arrangement of the power transmission link allows the amount of wiring on the fire truck 10 to be dramatically reduced. The power source delivers power to the interface modules 20 and 30, which act among other things as power distribution centers, and not directly to the output devices 50. Because the interface modules 20 and 30 are located so closely to the I/O devices 40 and 50, most of the I/O devices can be connected to the interface modules 20 and 30 using only a few feet of wire or less. This eliminates the need for a wire harness that extends the length of the fire truck (about forty feet) to establish connections for each I/O devices 40 and 50 individually.

[0029] Preferably, the configuration information required to implement the I/O processing is downloaded from the central control unit 14 to each interface module 30 (and each interface module 20) at power-up. Additionally, the harness connector that connects to each of the interface modules 20 and 30 are preferably electronically keyed, such that being connected to a particular harness connector provides the interface modules 20 and 30 with a unique identification code (for example, by tying various connector pins high and low to implement a binary code). The advantage of this approach is that the interface modules 20 and 30 become interchangeable devices that are customized only at power-up. As a result, if one of the interface modules 30 malfunctions, for example, a new interface module 30 can be plugged into the control system 12, customized automatically at power-up (without user involvement), and the control system 12 then becomes fully operational. This enhances the maintainability of the control system 12.



**[0030]** The interface modules 20 and the interface modules 30 are connected to the central control unit 14 by the communication network 60. The communication network may be implemented using a network protocol, for example, which is in compliance with the Society of Automotive Engineers (SAE) J1708/1587 and/or J1939 standards. The particular network protocol that is utilized is not critical, although all of the devices on the network should be able to communicate effectively and reliably.

**[0031]** Also connected to the communication network 60 are a plurality of displays 81 and 82. The displays 81 and 82 permit any of the data collected by the central control unit 14 to be displayed to the firefighters in real time. In practice, the data displayed by the displays 81 and 82 may be displayed in the form of text messages and may be organized into screens of data (given that there is too much data to display at one time) and the displays 81 and 82 may include membrane pushbuttons that allow the firefighters to scroll through, page through, or otherwise view the screens of data that are available. Additionally, although the displays 81 and 82 are both capable of displaying any of the information collected by the central control unit 14, in practice, the displays 81 and 82 are likely to be used only to display selected categories of information. For example, assuming the display 81 is located in the cab and the display 82 is located at the pump panel, the display 81 is likely to be used to display information that pertains to devices which are controlled from within the cab, whereas the display 82 is likely to be used to display information pertaining to the operation of the pump panel. Advantageously, the displays 81 and 82 give firefighters instant access to fire truck information at a single location, which facilitates both normal operations of the fire truck as well as troubleshooting if problems arise.

**[0032]** A personal computer may be connected to the control unit 14 by way of a communication link, which may be a modem link, an RS-232 link, an Internet link, and so on. The personal computer allows diagnostic software to be utilized for remote or local troubleshooting of the control system 12, for example, through direct examination of inputs, direct control of outputs, and viewing and controlling internal states, including interlock states. Because all I/O status information is stored in the central control unit 14, this information can be easily accessed and manipulated by the personal computer 85. If a problem is encountered, the personal computer can be used to determine whether the central control unit 14 considers all of the interface modules 20 and 30 to be "on-line" and, if not, the operator can check for bad connections and so on. If a

particular output device is not working properly, the personal computer can be used to trace the I/O status information from the switch or other input device through to the malfunctioning output device. For example, the personal computer can be used to determine whether the switch state is being read properly, whether all interlock conditions are met, and so on.

**[0033]** Also, in Fig. 1 several additional systems are shown which will now be briefly described before proceeding to a discussion of the operation of the control system 12. In particular, Fig. 1 shows an engine system including an engine 92 and an engine control system 91, a transmission system including a transmission 93 and a transmission control system 94, and an anti-lock brake system including an anti-lock brake control system 95 and anti-lock brakes 96. The transmission 93 is mechanically coupled to the engine 92, and is itself further mechanically coupled to a PTO system 97. The PTO system 97 allows mechanical power from the engine to be diverted to water pumps, aerial drive mechanisms, stabilizer drive mechanisms, and so on. In combination, the engine system, the transmission system and the PTO system form the power train of the fire truck 10.

**[0034]** By connecting the systems 92, 94 and 95 to the central control unit 14, an array of additional input status information becomes available to the control system 12. For example, for the engine, this allows the central control unit 14 to obtain I/O status information pertaining to engine speed, engine hours, oil temperature, oil pressure, oil level, coolant level, fuel level, and so on. For the transmission, this allows the central control unit 14 to obtain, for example, information pertaining transmission temperature, transmission fluid level and/or transmission state (1st gear, 2nd gear, and so on). Assuming that an off-the-shelf engine or transmission system is used, the information that is available depends on the manufacturer of the system and the information that they have chosen to make available.

**[0035]** Connecting the systems 92, 94 and 95 to the central control unit 14 is advantageous because it allows information from these subsystems to be displayed to firefighters using the displays 81 and 82. This also allows the central control unit 14 to implement various interlock conditions as a function of the state of the transmission, engine or brake systems. For example, in order to turn on the pump system (which is mechanically driven by the engine and the transmission), an interlock condition may be implemented that requires that the transmission be in neutral or 4th lockup (i.e., fourth

gear with the torque converter locked up), so that the pump can only be engaged when the wheels are disengaged from the power train. The status information from these systems can therefore be treated in the same manner as I/O status information from any other discrete I/O device on the fire truck 10. It may also be desirable to provide the central control unit 14 with a limited degree of control over the engine and transmission systems, for example, enabling the central control unit 14 to issue throttle command requests to the engine control system 91. This allows the central control unit to control the speed of the engine and therefore the voltage developed across the alternator that forms part of the power source.

**[0036]** Referring now to Fig. 2, a preferred embodiment of a fire truck 1210 with an aerial 1211 having an aerial control system 1212 is illustrated. By way of overview, the control system 1212 comprises an aerial central control unit 1214, a plurality of microprocessor-based interface modules 1221, 1225-1227, 1231-1233, a plurality of input devices 1240, and a plurality of output devices 1250. The central control unit 1214 and the interface modules 1221, 1225-1227, 1231-1233, are connected to each other by a communication network 1260. Displays 1280-1282 may also be included as part of control system 1212.

**[0037]** The control system 1212 is similar in most respect to the control system 12, with the primary difference being that the control system 1212 is used to control the output devices 1250 on the aerial 1211 based on input status information from the input devices 1240, rather than to control the output devices 50 on the chassis 11. The interface modules 1221, 1225-1227, 1231-1233, may be identical to the interface modules 20 and 30, respectively, and the central control unit 1214 may be identical to the central control unit 14 except that a different control program is required in connection with the aerial 1211. Accordingly, the discussion above regarding the interconnection and operation of the interface modules 20 and 30 with the input devices 40 and output devices 50 applies equally to the central control unit 1214, except to the extent that the control system 1212 is associated with the aerial 1211 and not with the chassis 11.

**[0038]** It is desirable to use a control system 1212 for the aerial 1211 which is separate from the control system 12 in order to provide a clear separation of function between systems associated with the aerial 1211 and systems associated with the chassis 11. Additionally, as a practical matter, many fire trucks are sold without aerials

and therefore providing a separate aerial control system enables a higher level commonality with respect to fire trucks that have aerials and fire trucks that do not have aerials.

**[0039]** The control system 1212 has complete motion control of the aerial 1211. To this end, the control program includes an envelope motion controller, load motion controller and interlock controller. Envelope motion control refers to monitoring the position of the aerial and preventing the aerial from colliding with the remainder of the fire truck 10, and otherwise preventing undesirable engagement of mechanical structures on the fire truck due to movement of the aerial. Envelope motion control is implemented based on the known dimensions of the aerial 1211 and the known dimensions and position of other fire truck structures relative to the aerial 1211 (e.g., the position and size of the cab 17 relative to the aerial 1211) and the position of the aerial 1211 (which is measured with feedback sensors 1244a and 1245a). The control system 1212 then disallows inputs that would cause the undesirable engagement of the aerial 1211 with other fire truck structures.

**[0040]** Load motion control refers to preventing the aerial from extending so far that the fire truck tips over due to unbalanced loading. Load motion control is implemented by using an appropriate sensor to measure the torque placed on the cylinder that mechanically couples the aerial 1211 to the remainder of the fire truck. Based on the torque and the known weight of the fire truck, it is determined when the fire truck is close to tipping, and warnings are provided to the operator by way of text messages and LED indicators.

**[0041]** Interlock control refers to implementing interlocks for aerial systems. For example, an interlock may be provided that require the parking brake be engaged before allowing the aerial to move, that require the stabilizers to be extended and set before moving the aerial 1211, that require that the aerial PTO be engaged before attempting to move the aerial, and so on.

**[0042]** Advantageously, therefore, the control system makes the operation of the aerial much safer. For example, with respect to load motion control, the control system 1212 automatically alerts firefighters if the extension of the aerial is close to causing the fire truck to tip over. Factors such as the number and weight of people in the basket 1219, the amount and weight of equipment in the basket 1219, the extent to which the

stabilizers are deployed, whether and to what extent water is flowing through aerial hoses, and so on, are taken into account automatically by the torque sensors associated with the cylinder that mounts the aerial to the fire truck. This eliminates the need for a firefighter to have to monitor these conditions manually, and makes it possible for the control system 1212 to alert an aerial operator to unsafe conditions, and puts less reliance on the operator to make sure that the aerial is operating under safe conditions.

**[0043]** Referring now to Fig. 3, an architecture for an alternative control system 1412 according to another preferred embodiment of the invention is illustrated. By way of overview, the control system 1412 comprises a plurality of microprocessor-based interface modules 1420, a plurality of input and output devices 1440 and 1450 (see Fig. 4) that are connected to the interface modules 1420, and a communication network 1460 that interconnects the interface modules 1420. The control system 1412 is generally similar to the control system 12, but includes several enhancements. The control system 1412 preferably operates in the same manner as the control system 12 except to the extent that differences are outlined are below.

**[0044]** The interface modules 1420 are constructed in generally the same manner as the interface modules 20 and 30 and each include a plurality of analog and digital inputs and outputs. The number and type of inputs and outputs may be the same, for example, as the vehicle interface modules 30. Preferably, as described in greater detail below, only a single type of interface module is utilized in order to increase the field serviceability of the control system 1412. Herein, the reference numeral 1420 is used to refer to the interface modules 1420 collectively, whereas the reference numerals 1421-1430 are used to refer to specific ones of the interface modules 1420. Also, the reference numerals 1440 and 1450 are used herein to refer to the input and output devices 1440 and 1450 collectively, whereas the reference numerals 1441-1443 and 1451-1453 are used herein to refer to specific ones of the input and output devices 1440 and 1450, respectively. The interface modules are described in greater detail in connection with Figs. 4-6.

**[0045]** Also connected to the communication network 1460 are a plurality of displays 1481 and 1482 and a data logger 1485. The displays 1481 and 1482 permit any of the data collected by the control system 1412 to be displayed in real time, and also display warning messages. The displays 1481 and 1482 also include membrane pushbuttons that allow the operators to scroll through, page through, or otherwise view the screens

of data that are available. The membrane pushbuttons may also allow operators to change values of parameters in the control system 1412. The data logger 1485 is used to store information regarding the operation of the vehicle 1410. The data logger 1485 may also be used as a "black box recorder" to store information logged during a predetermined amount of time (e.g., thirty seconds) immediately prior to the occurrence of one or more trigger events (e.g., events indicating that the vehicle 1410 has been damaged or rendered inoperative, such as when an operational parameter such as an accelerometer threshold has been exceeded).

[0046] Finally, Fig. 3 shows an engine system including an engine 1492 and an engine control system 1491, a transmission system including a transmission 1493 and a transmission control system 1494, and an anti-lock brake system including an anti-lock brake control system 1495. These systems may be interconnected with the control system 1412 in generally the same manner as discussed above in connection with the engine 92, the engine control system 91, the transmission 93, the transmission control system 94, and the anti-lock brake system 96 of Fig. 1.

[0047] Referring now also to Fig. 4-6, the structure and interconnection of the interface modules 1420 is described in greater detail. Referring first to Fig. 4, the interconnection of the interface modules 1420 with a power source 1500 is described. The interface modules 1420 receive power from the power source 1500 by way of a power transmission link 1502. The interface modules 1420 are distributed throughout the vehicle 1410, with some of the interface modules 1420 being located on the chassis 1417 and some of the interface modules 1420 being located on a variant module 1413. The variant module 1413 may be a module that is removable/replaceable to provide the vehicle 1410 with different types of functionality.

[0048] The control system is subdivided into three control systems including a chassis control system 1511, a variant control system 1512, and an auxiliary control system 1513. The chassis control system 1511 includes the interface modules 1421-1425 and the I/O devices 1441 and 1451, which are all mounted on the chassis 1417. The variant control system 1512 includes the interface modules 1426-1428 and the I/O devices 1442 and 1452, which are all mounted on the variant module 1413. The auxiliary control system 1513 includes the interface modules 1429-1430 and the I/O devices 1443 and 1453, which may be mounted on either the chassis 1417 or the variant module 1413 or both.

**[0049]** The auxiliary control system 1513 may, for example, be used to control a subsystem that is disposed on the variant module but that is likely to be the same or similar for all variant modules (e.g., a lighting subsystem that includes headlights, tail lights, brake lights, and blinkers). The inclusion of interface modules 1420 within a particular control system may also be performed based on location rather than functionality. For example, if the variant module 1413 has an aerial device, it may be desirable to have one control system for the chassis, one control system for the aerial device, and one control system for the remainder of the variant module. Additionally, although each interface module 1420 is shown as being associated with only one of the control systems 1511-1513, it is possible to have interface modules that are associated with more than one control system. It should also be noted that the number of sub-control systems, as well as the number of interface modules, is likely to vary depending on the application. For example, a mobile command vehicle is likely to have more control subsystems than a wrecker variant, given the large number of I/O devices usually found on mobile command vehicles.

**[0050]** When the variant module 1413 is mounted on the chassis 1417, connecting the chassis control system 1511 and the variant control system 1512 is achieved simply through the use of two mating connectors 1681 and 1682 that include connections for one or more communication busses, power and ground. The chassis connector 1682 is also physically and functionally mateable with connectors for other variant modules, i.e., the chassis connector and the other variant connectors are not only capable of mating physically, but the mating also produces a workable vehicle system. A given set of switches or other control devices 1651 on the dash (see Fig. 3) may then operate differently depending on which variant is connected to the chassis. Advantageously, therefore, it is possible to provide a single interface between the chassis and the variant module (although multiple interfaces may also be provided for redundancy). This avoids the need for a separate connector on the chassis for each different type of variant module, along with the additional unutilized hardware and wiring, as has conventionally been the approach utilized.

**[0051]** Referring next to Fig. 5, the interconnection of the interface modules 1420 by way of the communication network 1460 is illustrated. As previously indicated, the control system 1412 is subdivided into three control systems 1511, 1512 and 1513. In accordance with this arrangement, the communication network 1460 is likewise further

subdivided into three communication networks 1661, 1662, and 1663. The communication network 1661 is associated with the chassis control system 1511 and interconnects the interface modules 1421-1425. The communication network 1662 is associated with the variant control system 1512 and interconnects the interface modules 1426-1428. The communication network 1663 is associated with the auxiliary control system 1513 and interconnects the interface modules 1429-1430. Communication between the control systems 1511-1513 occurs by way of interface modules that are connected to multiple ones of the networks 1661-1663. Advantageously, this arrangement also allows the interface modules to reconfigure themselves to communicate over another network in the event that part or all of their primary network is lost.

**[0052]** Upon power up, the variant control system 1512 and the chassis control system 1511 exchange information that is of interest to each other. For example, the variant control system 1512 may communicate the variant type of the variant module 1413. Other parameters may also be communicated. For example, information about the weight distribution on the variant module 1413 may be passed along to the chassis control system 1511, so that the transmission shift schedule of the transmission 1493 can be adjusted in accordance with the weight of the variant module 1413, and so that a central tire inflation system can control the inflation of tires as a function of the weight distribution of the variant. Similarly, information about the chassis can be passed along to the variant. For example, where a variant module is capable of being used by multiple chassis with different engine sizes, engine information can be communicated to a wrecker variant module so that the wrecker variant knows how much weight the chassis is capable of pulling. Thus, an initial exchange of information in this manner allows the operation of the chassis control system 1511 to be optimized in accordance with parameters of the variant module 1413, and vice versa.

**[0053]** Referring next to Fig. 6, an exemplary one of the interface modules 1420 is shown in greater detail. The interface modules 1420 each include a microprocessor 1815 that is sufficiently powerful to allow each interface module to serve as a central control unit. The interface modules are identically programmed and each include a memory 1831 that further includes a program memory 1832 and a data memory 1834. The program memory 1832 includes BIOS (basic input/output system) firmware 1836, an operating system 1838, and application programs 1840, 1842 and 1844. The



application programs include a chassis control program 1840, one or more variant control programs 1842, and an auxiliary control program 1844. The data memory 1834 includes configuration information 1846 and I/O status information 1848 for all of the modules 1420-1430 associated with the chassis 1417 and its variant module 1413, as well as configuration information for the interface modules (N+1 to Z in Fig. 6) of other variant modules that are capable of being mounted to the chassis 1417.

**[0054]** It is therefore seen that all of the interface modules 1420 that are used on the chassis 1417 and its variant module 1413, as well as the interface modules 1420 of other variant modules that are capable of being mounted to the chassis 1417, are identically programmed and contain the same information. Each interface module 1420 then utilizes its network address to decide when booting up which configuration information to utilize when configuring itself, and which portions of the application programs 1840-1844 to execute given its status as a master or non-master member of one of the control systems 1511-1513. A master interface module may be used to provide a nexus for interface operations with devices external to the control systems 1511-1513. The interface modules are both physically and functionally interchangeable because the interface modules are capable of being plugged in at any slot on the network, and are capable of performing any functions that are required at that slot on the network.

**[0055]** This arrangement is highly advantageous. Because all of the interface modules 1420 are identically programmed and store the same information, the interface modules are physically and functionally interchangeable within a given class of vehicles. The use of a single type of interface module makes it easier to find replacement interface modules and therefore enhances the field serviceability of the control system 1412.

**[0056]** Additionally, as previously noted, each interface module 1420 stores I/O status information for all of the modules 1420-1430 associated with the chassis 1417 and its variant module 1413. Therefore, each interface module 1420 has total system awareness. As a result, it is possible to have each interface module 1420 process its own inputs and outputs based on the I/O status information in order to increase system responsiveness and in order to reduce the amount of communication that is required with the central control unit. The main management responsibility of the central control unit or master interface module above and beyond the responsibilities of all the other interface modules 1420 then becomes, for example, to provide a nexus for interface

operations with devices that are external to the control system of which the central control unit is a part.

**[0057]** The interface modules 1423 and 1425 are used to transmit I/O status information between the various control systems 1511-1513. Specifically, the interface module 1423 is connected to both the communication network 1661 for the chassis control system 1511 and to the communication network 1662 for the variant control system 1512. The interface module 1423 is preferably utilized to relay broadcasts of I/O status information back and forth between the interface modules 1421-1425 of the chassis control system 1511 and the interface modules 1426-1428 of the variant control system 1512. Similarly, the interface module 1425 is connected to both the communication network 1661 for the chassis control system 1511 and the to the communication network 1663 for the auxiliary control system 1513, and the interface module 1425 is preferably utilized to relay broadcasts of I/O status information back and forth between the interface modules 1421-1425 of the chassis control system 1511 and the interface modules 1429-1430 of the auxiliary control system 1513.

**[0058]** This arrangement is advantageous because it provides a fast and efficient mechanism for updating the I/O status information 1848 stored in the data memory 1834 of each of the interface modules 1420. Each interface module 1420 automatically receives, at regular intervals, complete I/O status updates from each of the remaining interface modules 1420. There is no need to transmit data request (polling) messages and data response messages (both of which require communication overhead) to communicate information pertaining to individual I/O states between individual I/O modules 1420. Although more I/O status data is transmitted, the transmissions require less overhead and therefore the overall communication bandwidth required is reduced.

**[0059]** This arrangement also increases system responsiveness. First, system responsiveness is improved because each interface module 1420 receives current I/O status information automatically, before the information is actually needed. When it is determined that a particular piece of I/O status information is needed, there is no need to request that information from another interface module 1420 and subsequently wait for the information to arrive via the communication network 1661. The most current I/O status information is already assumed to be stored in the local I/O status table. Additionally, because the most recent I/O status information is always available, there is no need to make a preliminary determination whether a particular piece of I/O status

information should be acquired. Boolean control laws or other control laws are applied in a small number of steps based on the I/O status information already stored in the I/O status table. Conditional control loops designed to avoid unnecessarily acquiring I/O status information are avoided and, therefore, processing time is reduced.

**[0060]** The technique described also provides an effective mechanism for detecting that an interface module 1420 has become inoperable. As just noted, the interface modules 1420 rebroadcast I/O status information at predetermined minimum intervals. Each interface module 1420 also monitors the amount of time elapsed since an update was received from each remaining interface module 1420. Therefore, when a particular interface module 1420 has become inoperable, the inoperability of the interface module 1420 can be detected by detecting the failure of the interface module 1420 to rebroadcast its I/O status information within a predetermined amount of time. Preferably, the elapsed time required for a particular interface module 1420 to be considered inoperable is several times the expected minimum rebroadcast time, so that each interface module 1420 is allowed a certain number of missed broadcasts before the interface module 1420 is considered inoperable. A particular interface module 1420 may be operable and may broadcast I/O status information, but the broadcast may not be received by the remaining interface modules 1420 due, for example, to noise on the communication network.

**[0061]** As previously noted, in one embodiment, the interface modules 1423 and 1425 are used to transmit I/O status information between the various control systems 1511-1513. In an alternative arrangement, the interface module 1429 which is connected to all three of the communication networks 1661-1663 could be utilized instead. Although less preferred, the interface module 1429 may be utilized to receive I/O status information from each of the interface modules 1421-1428 and 1430, assemble the I/O status data into an updated I/O status table, and then rebroadcast the entire updated I/O status table to each of the remaining interface modules 1421-1428 and 1430 at periodic or aperiodic intervals. Therefore, in this embodiment, I/O status information for all of the interface modules 1420 is routed through the interface module 1429 and the interface modules 1420 acquire I/O status information for non-local I/O devices 1440 and 1450 by way of the interface module 1429 rather than directly from the remaining interface modules 1420.

**[0062]** The preferred control systems and methods exhibit enhanced reliability and maintainability because it uses distributed power distribution and data collecting. The interface modules are interconnected by a network communication link instead of a hardwired link, thereby reducing the amount of wiring on the fire truck. Most wiring is localized wiring between the I/O devices and a particular interface module.

**[0063]** Additionally, the interface modules in the preferred systems are interchangeable units. If the control system were also applied to other types of equipment service vehicles (e.g., snow removal vehicles, refuse handling vehicles, cement/concrete mixers, military vehicles such as those of the multipurpose modular type, on/off road severe duty equipment service vehicles, and so on), the interface modules would even be made interchangeable across platforms since each interface module views the outside world in terms of generic inputs and outputs.

**[0064]** Referring to Figs. 7-10, a turret 610 that is controlled by a fire fighting vehicle control system 612 according to another embodiment of the invention is illustrated. The turret control system 612 may be implemented as a stand-alone system or in combination with one of the control system architectures described above. Except as specifically noted, the following discussion is generally applicable to both types of embodiments.

**[0065]** Referring first to Fig. 7, Fig. 7 is an overview of the preferred control system 612 for controlling the turret 610. The control system 612 includes a plurality of interface modules 613a-613d (collectively, "the interface modules 613"), turret I/O devices 614, and one or more operator interfaces 616a and 616b (collectively, "the operator interfaces 616"). The control system 612 may be implemented using the interface modules 613 regardless whether the control system 612 is implemented in combination with the control system 12. If the control system 612 is implemented in combination with the control system 12, then other, non-turret I/O devices may also be coupled to the interface modules 613. If the control system 612 is implemented as a stand-alone control system, then it may be preferable to replace the interface modules 613 with a single stand-alone electronic control unit.

**[0066]** As discussed in greater detail in connection with Figs. 8-9, the turret I/O devices 614 include actuators, position sensors, limit switches and other devices used to control the turret 610. The operator interfaces 616a and 616b each include display

618a and 618b (collectively, "the displays 618") and joysticks 619a and 619b (collectively, "the joysticks 619"). For example, the operator interface 616a may be located in a driver compartment of the fire fighting vehicle 620 and the other operator interface 616b may be located at another location, such as a rear or side vehicle location of the fire fighting vehicle 620, for example.

**[0067]** Assuming the control system 612 is implemented in combination with the control system 12 (with or without the enhancements of Figs. 1-8), the interface modules 613 are connected to each other by way of the communication network 60, previously described in connection with Figs. 1-2. Therefore, the interface modules shown in Fig. 7 are coupled to the same communication network 60 as the interface modules shown in Figs. 1-2. For simplicity, in describing the turret control system 612, all of the interface modules in the turret control system 612 as well as the interface modules shown in Figs. 1-2 will be referred to using the reference number 613. As previously described, the interface modules 613 are locally disposed with respect to the respective input and output devices to which each interface module is coupled so as to permit distributed data collection from the plurality of input devices and distributed power distribution to the plurality of output devices. Of course, each of the interface modules 613 may, in addition, be coupled to other non-local input devices and output devices. Further, the control system 612 can also include input devices and output devices which are not connected to the interface modules 613.

**[0068]** It may also be noted that if the control system 12 is employed, it is preferably implemented so as to incorporate the additional features described in connection with Figs. 3-6. Therefore, all of the interface modules 613 are preferably identically constructed and programmed. Further, each of the interface modules 613 broadcasts I/O status information on the communication network 60, and each of the interface modules 613 uses the I/O status broadcasts to maintain an I/O status table. Based on the I/O status information stored in the I/O status table maintained by each respective interface module 613, the respective interface module 613 executes pertinent portions of the control programs to control the output devices to which it is directly connected. It may also be noted that the fire fighting vehicle 620 may be implemented as an electric vehicle, as described in connection with Figs. 25-33 of U.S. Prov. No. 60/360,479 and U.S. Ser. No. 10/326,907, and/or include the network assisted scene management features of Figs. 34-41 of U.S. Prov. No. 60/360,479 and U.S. Ser. No. 10/326,907,

and/or be implemented to include the network-assisted monitoring, service and/or repair features described in connection with Figs. 42-67 of U.S. Prov. No. 60/360,479 and U.S. Ser. No. 10/326,907.

**[0069]** Referring now also to Fig. 8, Fig. 8 shows one embodiment of the turret 610, although it should be noted that the teachings herein do not depend on the exact configuration, construction, size or assembly of the turret 610. In this regard, it will be appreciated that the turret 610 is not necessarily drawn to scale in Fig. 8 relative to the fire fighting vehicle 620.

**[0070]** The turret 610 is shown to be of a type used on fire fighting vehicles such as municipal and airport fire trucks, crash trucks, emergency response vehicles, aerial platform trucks, ladder trucks, pumpers, tankers, and so on. Generally, such vehicles have a chassis and a vehicle body mounted on the chassis, with the chassis and vehicle body in combination including an operator compartment capable of receiving a human operator. The operator compartment further includes steering and throttle controls for receiving operator inputs to control movement of the fire fighting vehicle along a road. The turret 610 is mounted to a roof of the fire fighting vehicle 620, and is configured to deploy or dispense a fire fighting agent (i.e., water, foam, foaming agents, etc.). It should be understood that Fig. 8 merely illustrates one embodiment, and the turret 610 may be mounted anywhere and in any manner to the chassis/vehicle body of the fire fighting vehicle 620.

**[0071]** The turret 610 includes an adjustable mount assembly which includes a fire-extinguishing agent delivery system capable of transporting a fire-extinguishing agent through the mount assembly. In one embodiment, the adjustable mount assembly comprises a base 624, a first arm 626, a second arm 628, a third arm 630, and a nozzle 631. The arms 626-630 are hingedly moveable relative to each other and, in combination, form a boom for placing the nozzle 631 in a particular position and orientation. As will be appreciated, the arms 624-626 are not drawn to scale, and may have lengths which are significantly larger than those shown relative to the overall size of the fire fighting vehicle 620. Also, although three arms are shown which are movable in particular directions, fewer or more arms may be used which may be moveable in a different manner.

**[0072]** The base 624 is preferably configured to mount to the top of the fire fighting vehicle 620. In one embodiment, the base 624 is configured to swivel or rotate around an axis, as indicated by  $\theta 1$ . In another embodiment, the base 624 is fixed and is not able to rotate. Assuming that the base 624 is configured to rotate, and referring now also to Fig. 9, the base 624 may be coupled to a motor or other actuator (shown as actuator 632a) which causes the rotation of the base 624 in the direction of  $\theta 1$ . A position indicator or sensor 634a measures movement of the base 624 in the  $\theta 1$  direction, and a pair of limit switches 636a ascertain whether the base 624 is at one of the boundaries of movement in the  $\theta 1$  direction.

**[0073]** The first arm 626 is rotatably coupled to the base 624, and is mounted for hinged movement, as indicated by  $\theta 2$ . The first arm 626 may be coupled to a motor or other actuator (shown as actuator 632b) which causes the rotation of the first arm 626 around  $\theta 2$ . A position sensor 634b measures movement of the first arm 626 in the  $\theta 2$  direction, and a pair of limit switches 636b ascertain whether the first arm 626 is at one of the boundaries of movement in the  $\theta 2$  direction.

**[0074]** The second arm 628 is rotatably coupled to the first arm 626 and is mounted for hinged movement, as indicated by  $\theta 3$ . The second arm 628 may be coupled to a motor or other actuator (shown as actuator 632c) which causes the rotation of the second arm 628 around  $\theta 3$ . A position sensor 634c measures movement of the second arm 628 in the  $\theta 3$  direction, and a pair of limit switches 636c ascertain whether the second arm 628 is at the one of the boundaries of movement in the  $\theta 3$  direction.

**[0075]** The second arm 628 may also have a length which is adjustable (i.e., extendable or retractable) as indicated by L1. The second arm 628 may further be coupled to a motor or other actuator (shown as actuator 632d) which causes the extension of the second arm 628 along L1. Adjustments along L1 allow for changes in the height of the turret 610 without requiring the rotation of any arm. A position sensor 634d measures movement of the second arm 628 in the L1 direction, and a pair of limit switches 636d ascertain whether the second arm 628 is at one of the boundaries of movement in the L1 direction.

**[0076]** The third arm 630 is rotatably coupled to the second arm 628, and is mounted for hinged movement, as indicated by  $\theta 4$ . The third arm 630 may be coupled to a motor or other actuator (shown as actuator 632e) which causes the rotation of the third arm

630 around  $\theta_4$ . A position sensor 634e measures movement of the third arm 630 in the  $\theta_4$  direction, and a pair of limit switches 636e ascertain whether the third arm 630 is at the one of the boundaries of movement in the  $\theta_4$  direction.

[0077] The third arm 630 may also swivel around a vertical axis, as indicated by  $\theta_5$ . The third arm 630 may further be coupled to a motor or other actuator (shown as actuator 632f) which causes the rotation of the third arm 630 around  $\theta_5$ . A position sensor 634f measures movement of the third arm 630 in the  $\theta_5$  direction, and a pair of limit switches 636f ascertain whether the third arm 630 is at the one of the boundaries of movement in the  $\theta_5$  direction.

[0078] The base 624, the first arm 626, the second arm 628, and the third arm 630 are fluidly connected, allowing the flow of a fire fighting agent to pass from the base 624 to the third arm 630. Fire fighting agent enters the base 624 from a source such as a pump, hydrant, pipe, etc. The nozzle 631 is mounted on a free end of the third arm 630 and receives the fire-extinguishing agent transported by the arms 626-630. The position and orientation of the nozzle 631 are controlled by a turret controller 660 (discussed below in connection with Fig. 10) to direct the flow of fire fighting agent toward an intended target or other region of interest such as a fire, chemical spill, etc. Furthermore, the nozzle 631 may be capable of controlling the flow rate of fire fighting agent (as indicated by F1). The nozzle 631 may further be coupled to a motor or actuator (shown as actuator 632g) which controls the flow rate setting for the nozzle 631. A position or flow rate sensor 634g measures the nozzle setting, and a set of switches or other sensors 636g provide information regarding whether the setting of the nozzle 631 is at particular levels (e.g., full on, full off). The flow rate sensor 634g may measure the flow rate at the nozzle 631, or may measure the amount of fire fighting agent remaining in an on-board storage tank and deduce flow rate by calculating the rate of change in the amount of remaining fire fighting agent.

[0079] In an exemplary embodiment, the turret 610 is a Snozzle Model C-50 or 50A available from Crash Rescue Equipment Service, Inc. of Dallas, Texas. In an alternative embodiment, the turret 610 is a Snozzle Model P-50 or 50A also available from Crash Rescue Equipment Service, Inc. of Dallas, Texas. In another alternative embodiment, the turret 610 may be a Rhino Bumper Turret available from Crash Rescue Equipment Service, Inc. of Dallas, Texas. As previously indicated, however, the particular



configuration of the turret is not important and other turret systems from other manufacturers could also be used.

**[0080]** As shown in Fig. 9, the position indicators or sensors 634a-634g (collectively, "the position sensors 634") and the limit switches 636a-636g (collectively, "the limit switches 636") are connected as input devices to the interface modules 613a-613b. The interface modules 613a-613b thereby receive the position information pertaining to the position and orientation of the nozzle 631. The actuators 632a-632g (collectively, "the actuators 632") are connected as output devices to the interface modules 613a-613b. The interface modules 613a-613b provide the actuators 632 with control signals to adjust the base 624 and the arms 626-630 to thereby adjust the position and orientation of the nozzle 631. The actuators 632, the position sensors 634 and the limit switches 636 collectively correspond to "the turret I/O devices" which are labeled with the reference number 614 in Fig. 7. Other I/O devices may also be used. The interface module 613a may be located near the nozzle 631 of the turret 610 and the interface module 613b may be located near the base 624 of the turret 610, with the turret I/O devices 614 preferably being connected to a particular interface module 613a, 613b based on location.

**[0081]** The position sensors 634 may be encoders, resolvers or other suitable position measuring devices. The actuators 632 may be electric motors, especially if the fire fighting vehicle is implemented as an electric vehicle (for example, the electric vehicle 1910 described in connection with Figs. 25-33 of U.S. Prov. No. 60/360,479 and U.S. Ser. No. 10/326,907). Alternatively, the actuators 632 may for example be electrically controlled valves that control the flow of hydraulic power to the turret if turret movement is hydraulically driven. Other arrangements could also be used.

**[0082]** The joysticks 619 are preferably multi-axis joysticks, with the control system 612 being capable of receiving operator inputs from either joystick 619a, 619b and using the operator inputs to control the turret 610, as detailed below. In one embodiment, the joysticks are three-axis joysticks, with left to right corresponding to boom up and boom down ( $\theta_2$  and  $\theta_3$  control), forward and back corresponding to nozzle up and nozzle down ( $\theta_4$  control), and twist corresponding to nozzle left and nozzle right ( $\theta_5$  control). In this configuration, the base 624 is held stationary. Additional or alternative operator input devices may be used if the base 624 is not held stationary, if the joysticks 619 are implemented using two-axis joysticks rather than three-axis joysticks, or if a different

type of operator input device is desired. In practice, the configuration of the joysticks may vary from system to system depending on user preferences. As described in greater detail below, in an alternative embodiment, the fire fighting vehicle 620 includes two turrets, with each of the joysticks 619a and 619b being useable to control either or both turrets, depending on how the turret controller 660 is configured.

**[0083]** Referring now to Fig. 10, the arrangement of Figs. 7-9 can be used to implement a variety of advantageous features, such as turret envelope control, turret targeting, turret pan, turret deploy, turret store and other features. Figure 10 is a block diagram of a turret control system that implements such features. The turret control system 612 comprises the operator interface 616, a turret motion controller 660, the actuators 632, the position sensors 634, and a plurality of other input devices such as a fire position indicator 635, described in greater detail below.

**[0084]** In the preferred embodiment, the turret motion controller 660 is implemented using interface modules, and preferably comprises the interface modules 613a and 613b of Fig. 7. According to this arrangement, and as previously indicated, all of the interface modules 613 are preferably identically programmed, and the interface modules 613 each include control programs which implement a plurality of control modules 661 including an envelope control module 662, a turret targeting module 664, a turret learn module 665, a turret pan module 668, a turret deploy module 670, and a turret store module 672. The interface module 613a then receives I/O status information from other interface modules 613 through I/O status broadcasts, and maintains an I/O status table based on the I/O status broadcasts and based on locally acquired/determined I/O status information. The interface module 613a then controls the actuators 632a-632d by executing those portions of the control programs pertinent to the actuators 632a-632d and using the I/O status information stored in its I/O status table. The interface module 613b operates in the same manner, except that it controls the actuators 632g-632f by executing those portions of the control programs pertinent to the actuators 632g-632f. As a practical matter, there is a significant overlap between the portions of the control program pertinent to the actuators 632a-632d and the portions of the control program pertinent to the actuators 632e-632g. The interface modules 613c and 613d are not shown in Fig. 10, although it is to be understood that the input information from the operator interfaces 616 is received by the interface modules 613c and 613d and

transmitted from the interface modules 613c and 613d to the interface modules 613a and 613b in the form of an I/O status broadcast over the communication network 60.

**[0085]** Referring to Figs. 8, 11, and 12, a system and method for positioning a turret 610 according to an exemplary embodiment is illustrated. A fire fighting vehicle 620 may be configured according to any previously described embodiments, unless specifically stated otherwise. Accordingly, fire fighting vehicle 620 may include any of a number of combinations and configurations of the control systems previously described. Also, the components (e.g., turret 610, nozzle 631, etc.) of fire fighting vehicle 620 may be configured according to any of the previously described embodiments, except as specifically noted. Thus, any one or combination of the previous embodiments may be employed in conjunction with fire fighting vehicle 620.

**[0086]** A turret positioning system as disclosed herein may be used on turrets for other equipment service vehicles such as vehicles with derricks, buckets for lifting a person, etc. For example, a military vehicle that has an attached pallet loading crane may be configured according to the present disclosure to control and determine the position of the crane. Accordingly, the teachings described herein should not be construed as only applying to fire fighting vehicles.

**[0087]** Referring to Fig. 11, an exemplary embodiment of a system for measuring the position of base 624 for turret 610 is shown. Base 624 includes stationary support 844 and rotatable apparatus 846. Base 624 is used to mount turret 610 to fire fighting vehicle 620 so that turret 610 may be rotated relative to fire fighting vehicle 620. In this embodiment, as shown in Fig. 11, support 844 is bolted to a corresponding portion of fire fighting vehicle 620 so that turret 610 rotates in a plane that is approximately horizontal. However, base 624 may be mounted to fire fighting vehicle 620 in any of number of ways such as by welding. Base 624 may also be formed as an integral part of fire fighting vehicle 620. In this situation, base 624 is generally the area where apparatus 846 is rotatably coupled to fire fighting vehicle 620. In an exemplary embodiment, base 624 is mounted to the frame or an extension of the frame of fire fighting vehicle 620. Mounting turret 610 to the frame of fire fighting vehicle 620 provides greater stability and strength to turret 610. This is especially useful if turret 610 includes a nozzle 631 that is used to pierce through the outer layer of a structure such as an airplane.

**[0088]** Support 844 and apparatus 846 are coupled together so that apparatus 846 can rotate relative to support 844. As shown in Fig. 11, apparatus 846 includes a sleeve 862 that is positioned on the inside of an aperture 856 located in support 844, thus coupling support 844 and apparatus 846 together. In order for apparatus 846 to be able to rotate, a bearing is provided at the interface of support 844 and sleeve 862. In another embodiment, support 844 may be provided with a sleeve that extends into a cavity of apparatus 846 in a similar manner. Other suitable configurations may also be used to allow apparatus 846 to rotate relative to support 844.

**[0089]** As shown in Fig. 11, support 844 includes a first or base gear 848, a bottom portion 850, aperture 856, and blocks 858. Base gear 848 is configured so that it does not move relative to support 844 and is fixedly mounted to bottom portion 850. Base gear 848 meshes with a second or sensor gear 852 and a third or drive gear 854, both of which rotate relative to base gear 848 and are mounted to apparatus 846. Aperture 856 may be used as a housing for power links, communication network lines, hydraulic lines, fire fighting agent lines, etc. that are used in turret 610. Blocks 858 are mounted (e.g., welded, bolted, etc.) to bottom portion 850 and act to limit the range of rotation of apparatus 846. In Fig. 11, blocks 858 are used to limit the range of rotation of apparatus 846 to approximately 30 degrees. Thus, apparatus 846 can rotate approximately 15 degrees to the right or to the left of a center position of turret 610. In another exemplary embodiment, blocks 858 are used to limit the range of rotation of apparatus 846 to approximately 60 degrees. In this embodiment, apparatus 846 can rotate approximately 30 degrees to the right or to the left of a center position of turret 610. In other exemplary embodiments, apparatus 846 may be configured to have a range of rotation not greater than approximately 90 degrees, and desirably between approximately 50 degrees and approximately 70 degrees. In further embodiments, apparatus 846 may be configured to rotate one or more full turns.

**[0090]** Apparatus 846 is generally the portion of turret 610 that rotates in relation to support 844 and/or fire fighting vehicle 620. As shown in Figs. 11 and 12, apparatus 846 includes sensor gear 852, drive gear 854, and a position sensor 860. As previously described, sensor gear 852 and drive gear 854 mesh with base gear 848. Drive gear is coupled to a source of power for rotating apparatus 846. The source of power may be a hydraulic pump, electric motor, pneumatic drive, etc. Sensor gear 852 is coupled to

position sensor 860, which measures the amount that sensor gear 852 and, by extension, apparatus 846 rotates.

**[0091]** In other embodiments, gears 848, 852, and 854 can be configured in a number of ways to facilitate rotation of apparatus 846. In the following embodiments, gears 848, 852, and 854 are referred to generically as gears because, depending on the configuration, the gears may be stationary or rotatable, coupled to the base or apparatus, etc. In one embodiment, gear 848 may be configured to rotate relative to bottom portion 850 of support 844. In this embodiment, gear 854 is stationary so that as gear 848 rotates, apparatus 846 also rotates. In another embodiment, gear 848 is fixedly mounted to apparatus 846 so that gear 848 does not rotate relative to apparatus 846. Gear 854 is coupled to support 844 and meshes with gear 848 so that as gear 854 rotates, apparatus 846 also rotates. Also, in any of these embodiments, sensor gear 852 may be configured to mesh with gear 854 or gear 848 or one or a number of gears that may be located between sensor gear 852 and gear 854 or gear 848. In general gear 852 can be configured in a number of ways so that as apparatus 846 rotates, sensor gear 852 also rotates, thus allowing position sensor 860 to measure the position of apparatus 846.

**[0092]** As shown in Figs. 11 and 12, position sensor 860 is mounted to apparatus 846 using bracket 864. Position sensor 860 is also in communication with a communication network that is included as part of the above described control systems by way of communication link 866. In this manner, position sensor 860 can communicate the position of turret 610 to a control system that may be included with fire fighting vehicle 620 as described above. Position sensor 860 may also be configured to communicate the position of turret 610 to a stand alone display or control system that controls or displays the position and/or movement of turret 610. Of course, the number of uses for the position information provided by position sensor 860 is virtually unlimited.

**[0093]** Position sensor 860 may be any of a number of suitable rotary, linear, analog, digital, magnetic, etc. position sensors. In general, rotary position sensors, or position sensors that are particularly suited to measuring rotary movement are desirable to use as position sensor 860. In an exemplary embodiment, position sensor 860 is a rotary position sensor, model number IPS 6501 A502, available from Novotechnik of Southborough, MA.

[0094] The present system for measuring the position of turret 610 may be used as described above. The present system may be particularly useful in conjunction with the operations previously described such as turret pan, turret deploy, and turret store operations.

[0095] Throughout the specification, numerous advantages of preferred embodiments have been identified. It will be understood of course that it is possible to employ the teachings herein so as to without necessarily achieving the same advantages. Additionally, although many features have been described in the context of a vehicle control system comprising multiple modules connected by a network, it will be appreciated that such features could also be implemented in the context of other hardware configurations. Further, although various figures depict a series of steps which are performed sequentially, the steps shown in such figures generally need not be performed in any particular order. For example, in practice, modular programming techniques are used and therefore some of the steps may be performed essentially simultaneously. Additionally, some steps shown may be performed repetitively with particular ones of the steps being performed more frequently than others. Alternatively, it may be desirable in some situations to perform steps in a different order than shown.

[0096] As previously noted, the construction and arrangement of the elements of the turret control system shown in the preferred and other exemplary embodiments are illustrative only. Although only a few embodiments of the present inventions have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible without materially departing from the novel teachings and advantages of the subject matter recited in the claims. Accordingly, all such modifications are intended to be included within the scope of the present invention as defined in the appended claims. In the claims, any means-plus-function clause is intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the preferred and other exemplary embodiments without departing from the scope of the present inventions as expressed in the appended claims.

## WHAT IS CLAIMED IS:

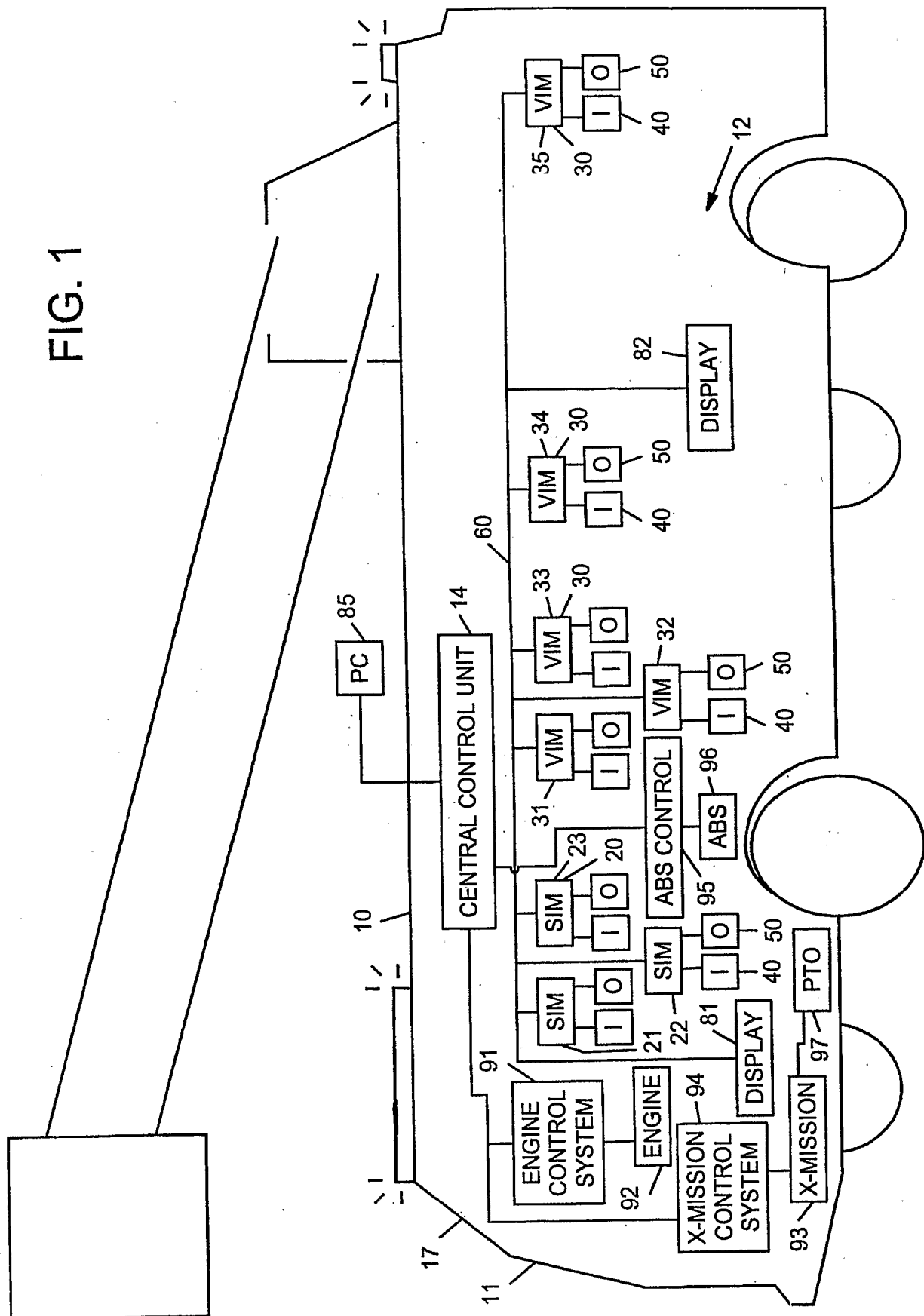
1. A turret for a vehicle comprising:
  - a first gear coupled to the vehicle, the first gear being stationary relative to the vehicle;
  - an apparatus coupled to the vehicle and configured to rotate relative to the vehicle, the apparatus including a second gear which is rotatably coupled to the first gear and is configured to rotate as the apparatus rotates relative to the vehicle; and
  - a position sensor coupled to the second gear, the position sensor being used to determine the position of the apparatus.
2. The turret according to claim 1 wherein the apparatus rotates relative to the vehicle in an approximately horizontal plane.
3. The turret according to claim 1 wherein the position sensor is a rotary potentiometer.
4. The turret according to claim 1 wherein the apparatus further comprises a third gear rotatably coupled to the first gear, the third gear being configured to drive the rotation of the apparatus.
5. The turret according to claim 4 wherein the third gear is driven hydraulically.
6. The turret according to claim 4 wherein the second gear meshes with the third gear.
7. The turret according to claim 1 wherein the second gear is configured to drive the rotation of the apparatus.
8. The turret according to claim 1 wherein the apparatus is configured to dispense fire fighting agent.

9. The turret according to claim 1 wherein the apparatus is configured to rotate through a range of rotation that is not greater than approximately 90 degrees.
10. A fire fighting vehicle comprising:  
a first gear fixedly mounted to the vehicle;  
an apparatus coupled to the vehicle and configured to rotate relative to the vehicle, the apparatus including a second gear which is rotatably coupled to the first gear and is configured to rotate as the apparatus rotates relative to the base; and  
a position sensor coupled to the second gear, the position sensor being configured to measure the position of the apparatus.
11. The fire fighting vehicle according to claim 10 wherein the apparatus rotates in an approximately horizontal plane.
12. The fire fighting vehicle according to claim 10 wherein the position sensor is a rotary potentiometer.
13. The fire fighting vehicle according to claim 10 wherein the apparatus further comprises a third gear rotatably coupled to the first gear, the third gear being configured to drive the rotation of the apparatus.
14. The fire fighting vehicle according to claim 13 wherein the third gear is driven hydraulically.
15. The fire fighting vehicle according to claim 10 wherein the apparatus is configured to dispense a fire fighting agent.
16. The fire fighting vehicle according to claim 10 wherein the apparatus is configured to rotate through a range of rotation that is not greater than approximately 90 degrees.
17. The fire fighting vehicle according to claim 10 wherein the first gear meshes with the second gear.



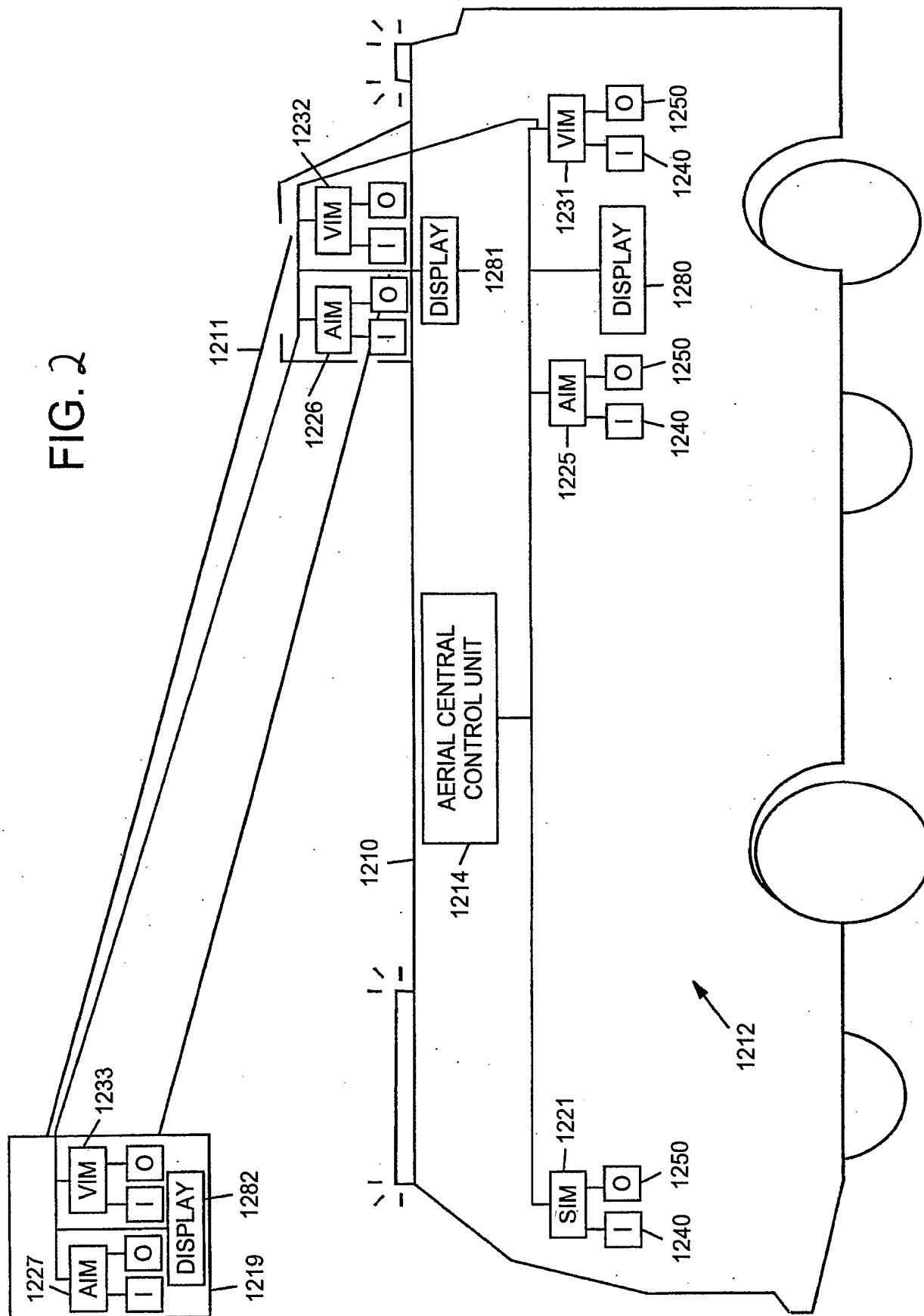
18. The fire fighting vehicle according to claim 10 wherein the apparatus is extendable.

FIG. 1



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FIG. 2



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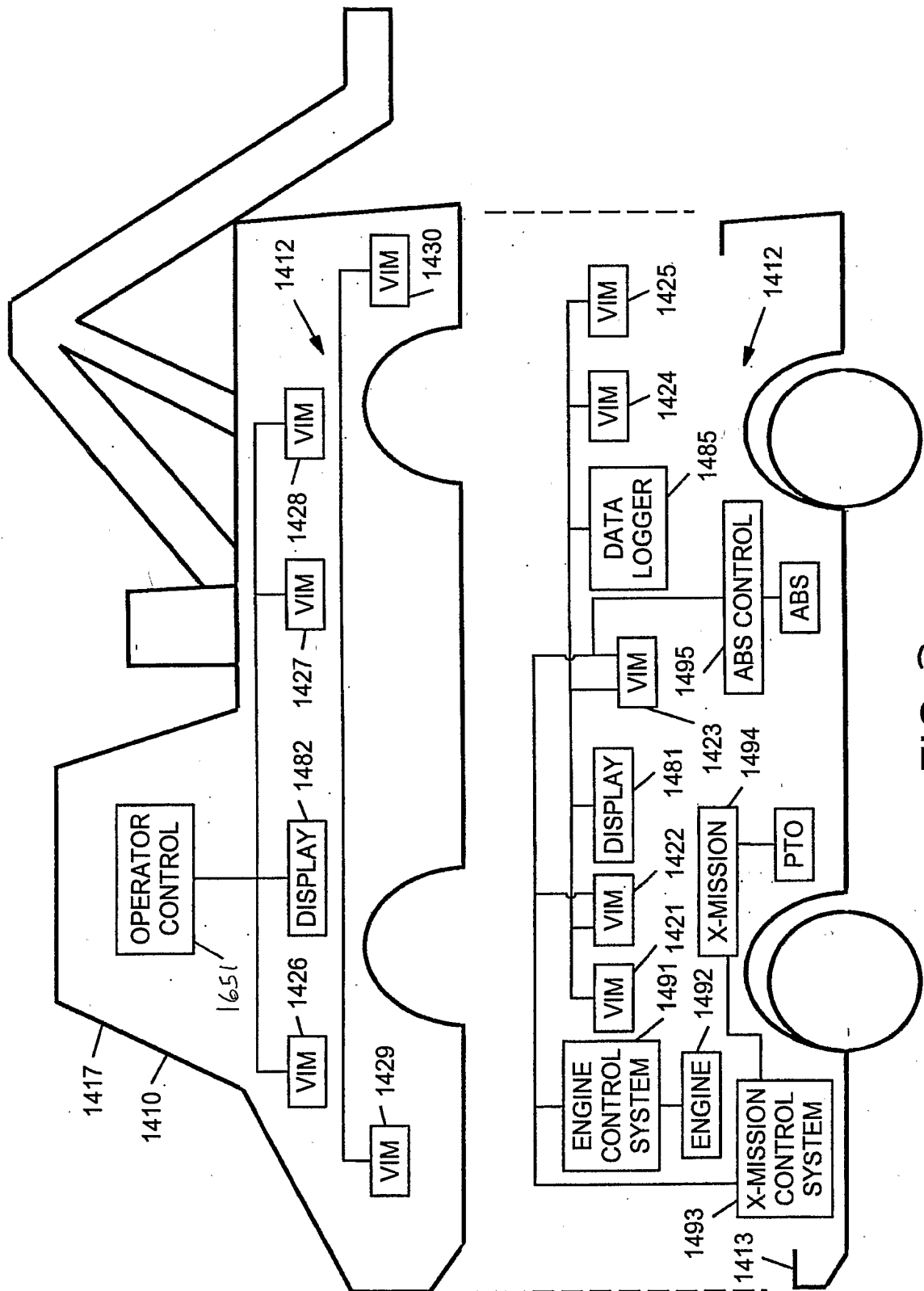


FIG. 3

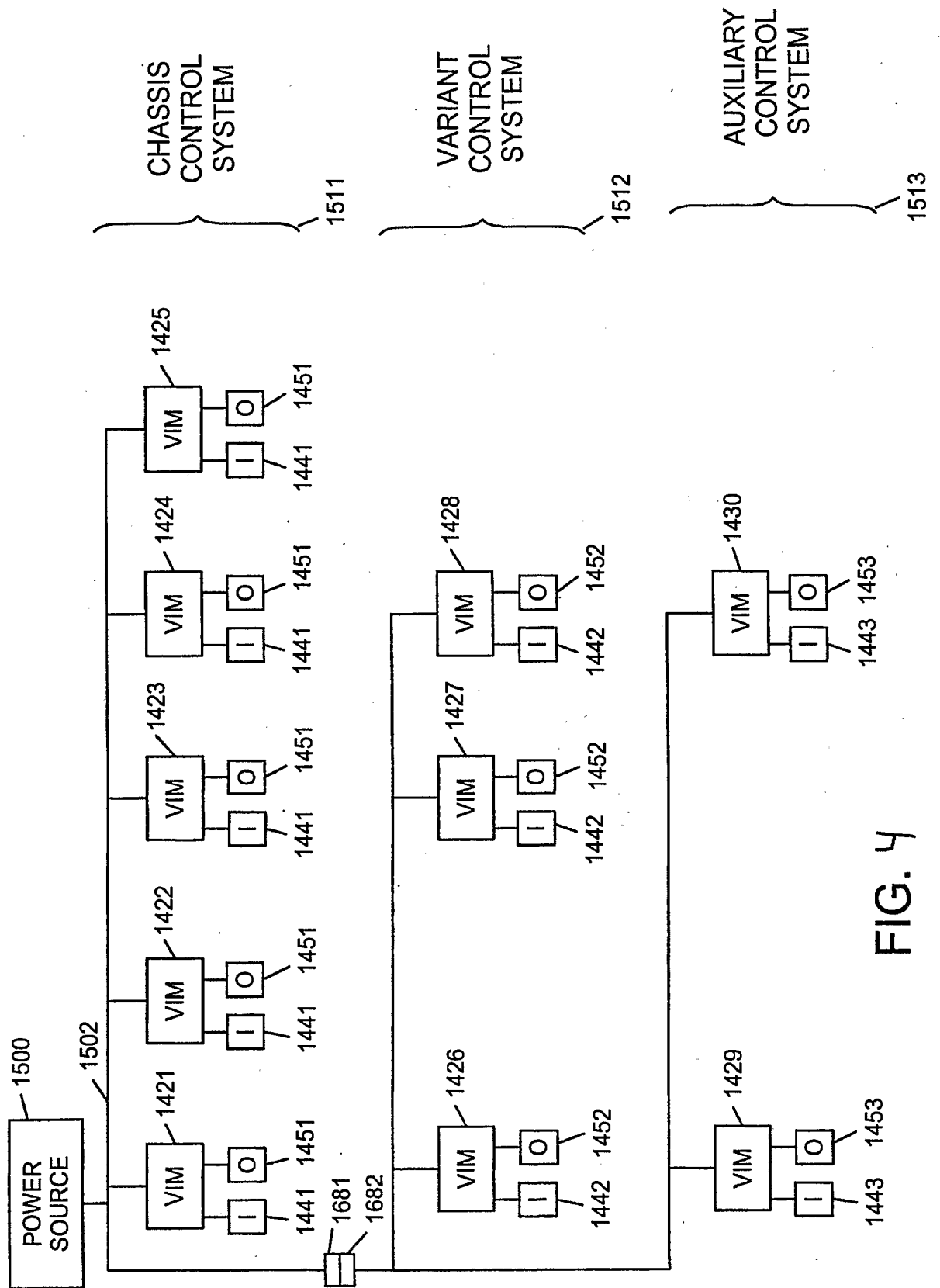


FIG. 4

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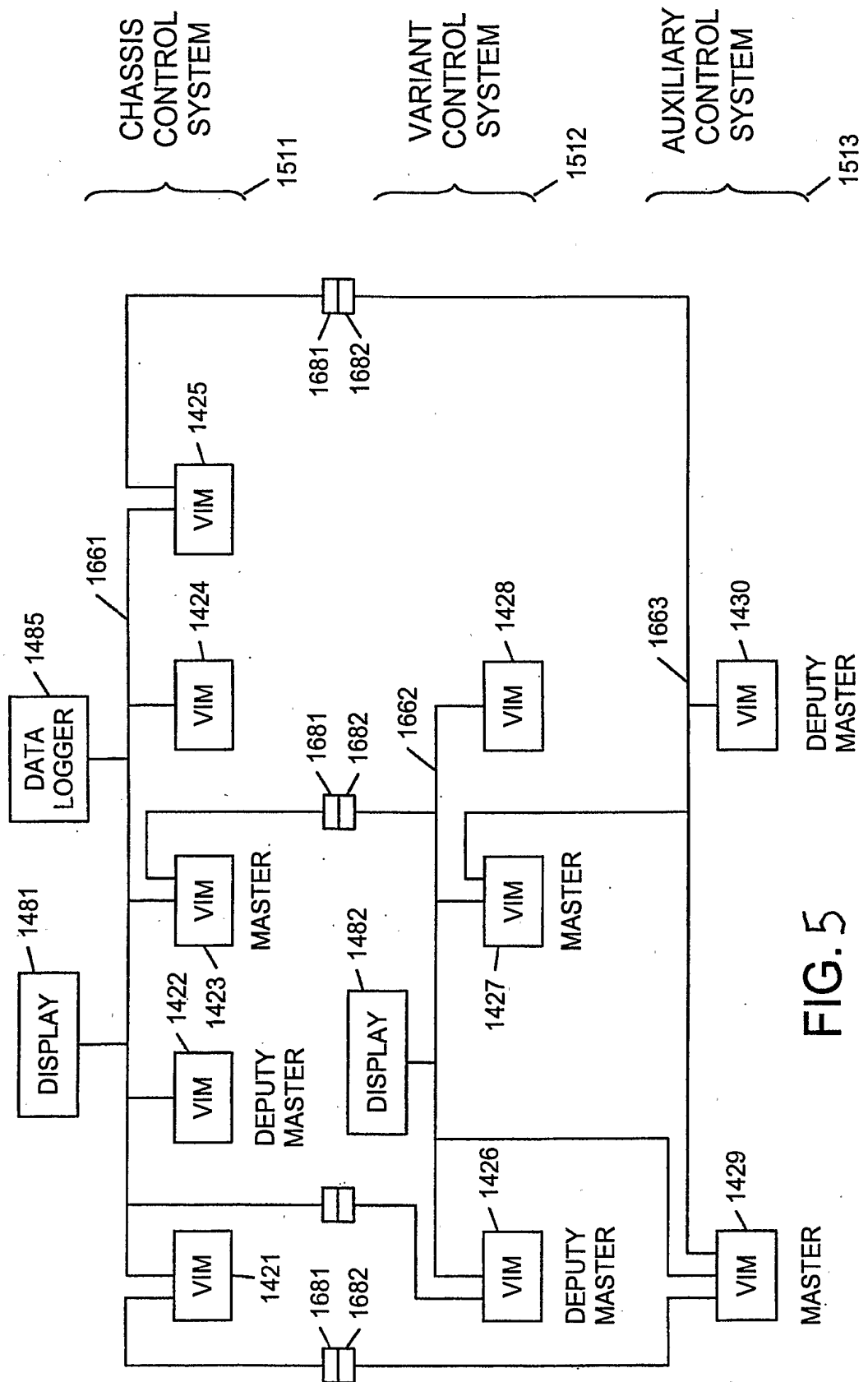


FIG. 5

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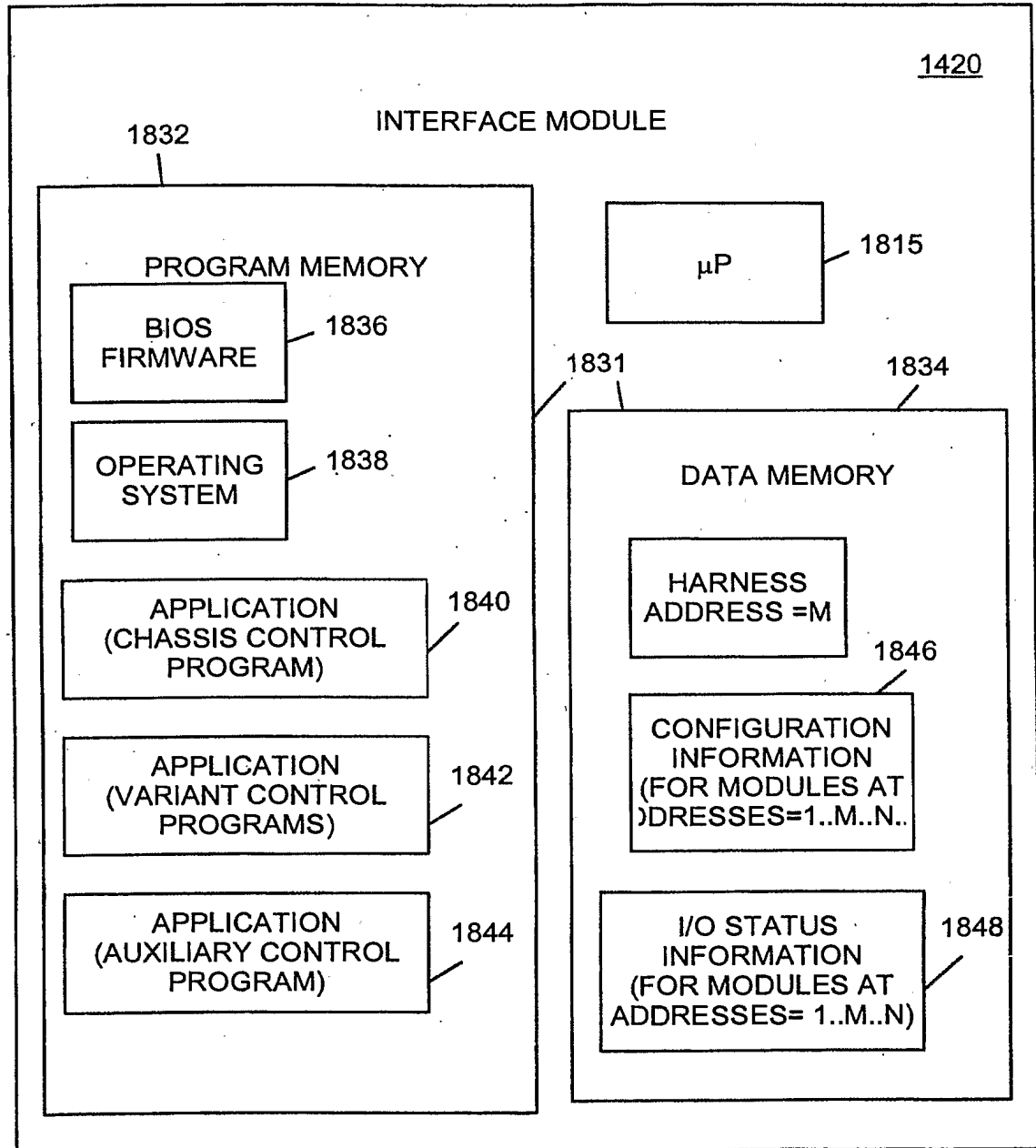


FIG. 6

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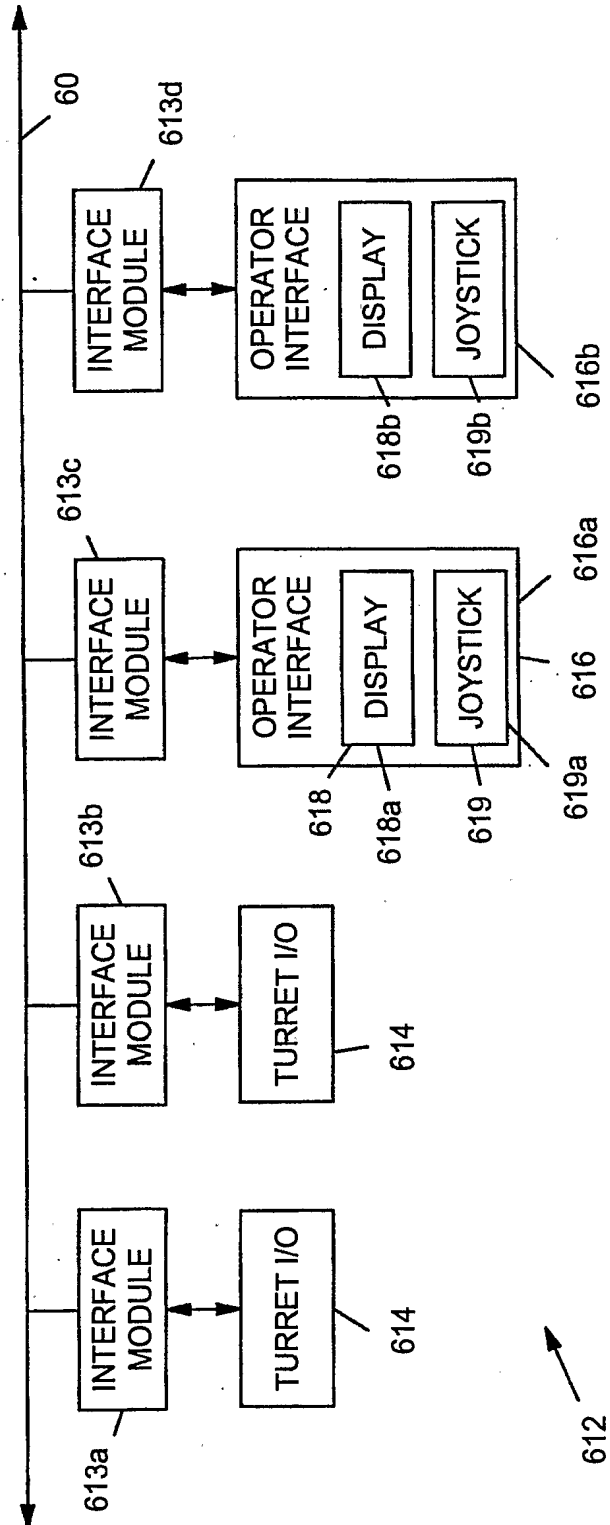
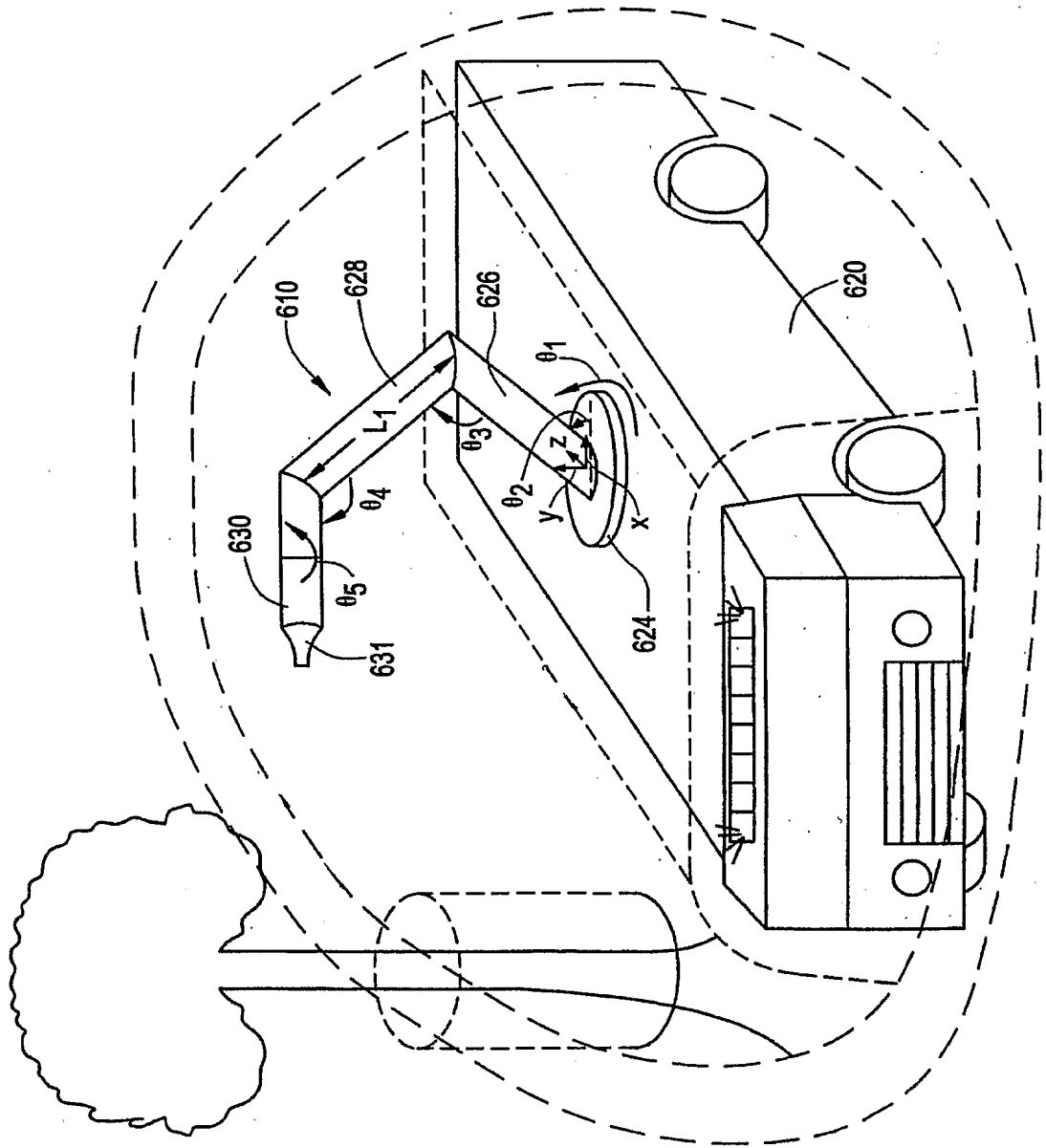


FIG. 7



FIG. 8



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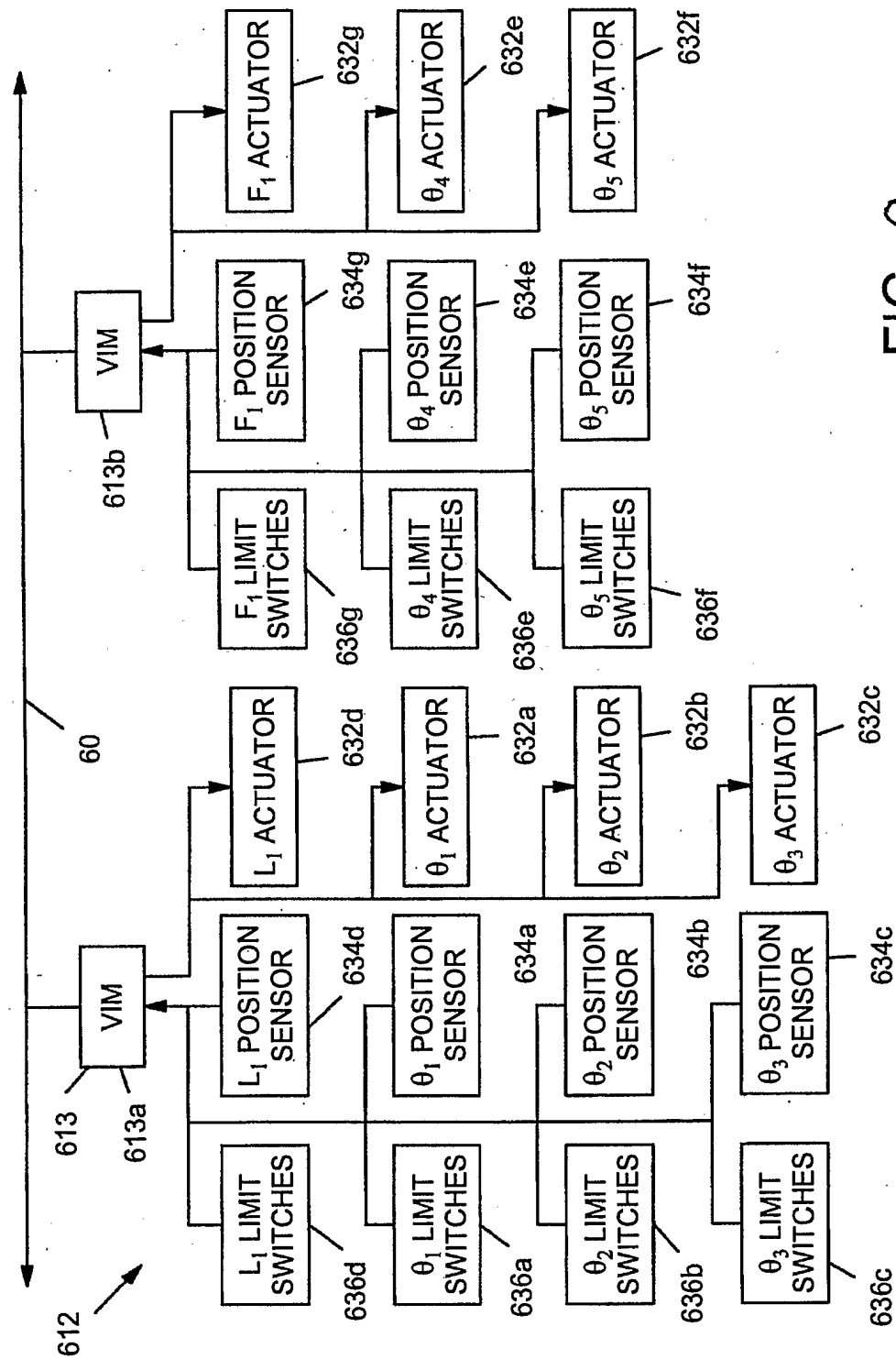


FIG. 9

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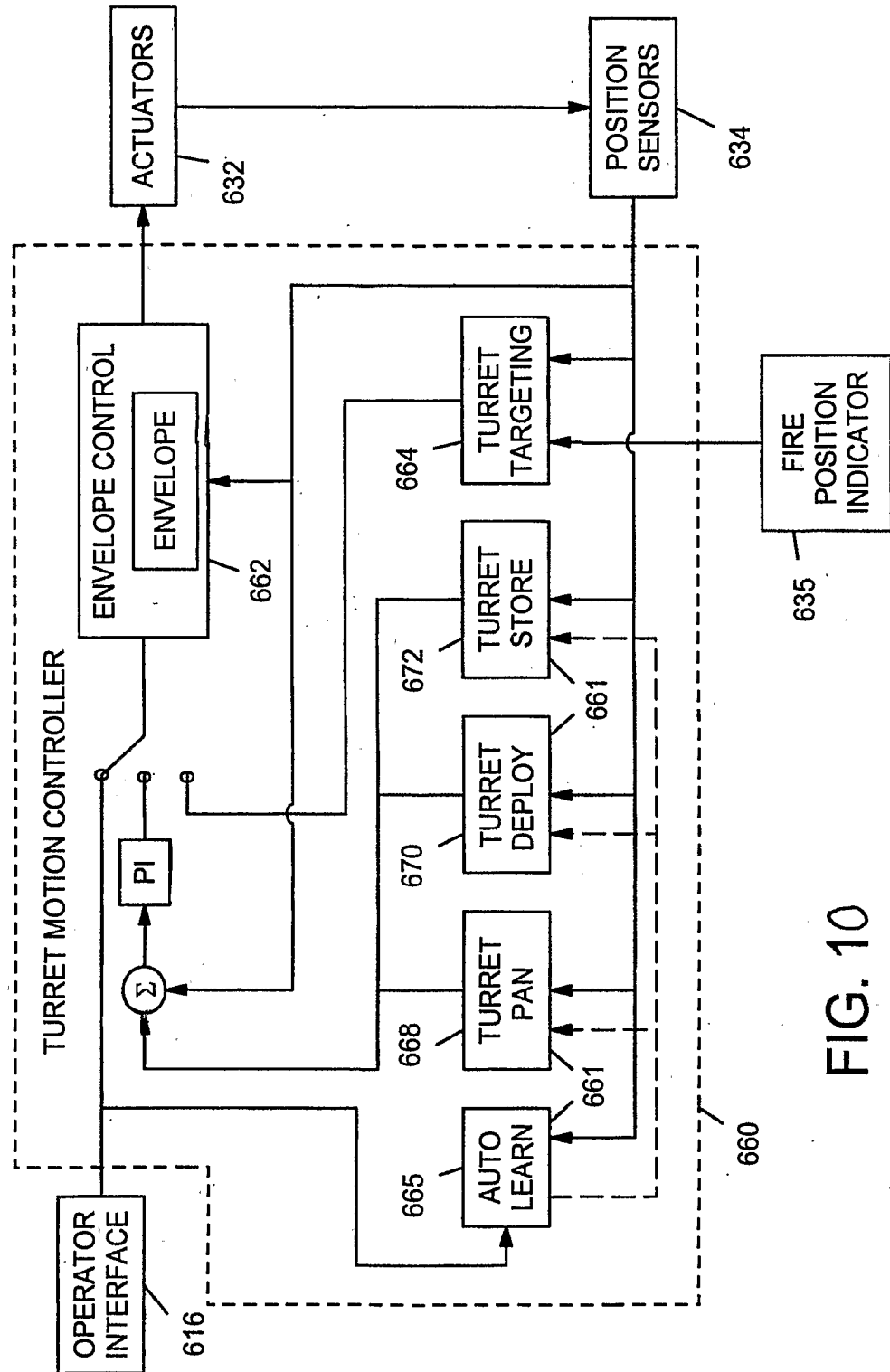
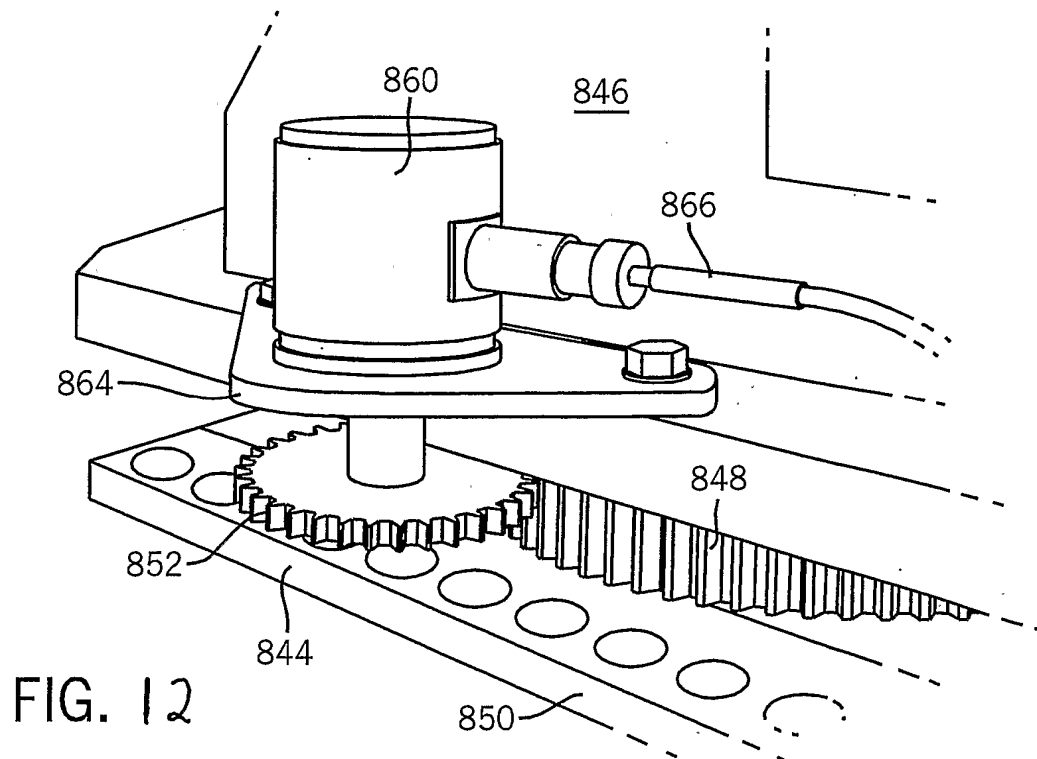
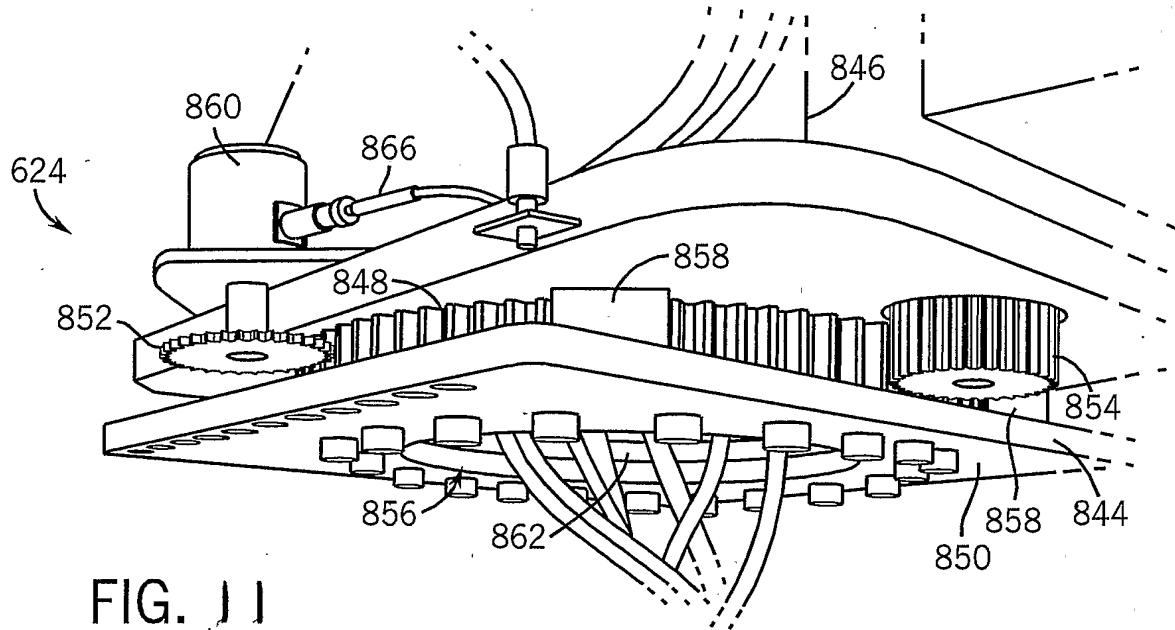


FIG. 10

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# INTERNATIONAL SEARCH REPORT

International Application No  
/US2004/014925

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 F41A27/26 A62C27/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 F41A A62C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 520 943 A (LUDEMAN EDWIN H) 5 September 1950 (1950-09-05)	1-5, 7, 9
Y	column 4, line 48 - column 5, line 35; figure 3	8, 10-16, 18
Y	----- DE 200 15 197 U (CALLIES OLIVER) 26 October 2000 (2000-10-26) the whole document	8, 10-16, 18
A	----- US 4 196 380 A (GUSTAVSSON VARNE ET AL) 1 April 1980 (1980-04-01) column 3, lines 3-40; figures 5, 6	1-18
A	----- DE 977 732 C (LICENTIA GMBH) 12 December 1968 (1968-12-12) column 2, lines 46-50 column 3, lines 24-32 ----- -/--	1-18

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

6 October 2004

Date of mailing of the international search report

20/10/2004

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# INTERNATIONAL SEARCH REPORT

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US2004/014925

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 300 918 A (BECKER) 5 April 1994 (1994-04-05) the whole document -----	3, 12

# INTERNATIONAL SEARCH REPORT

Information on patent family members

onal Application No

US2004/014925

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2520943	A	05-09-1950	NONE	
DE 20015197	U	26-10-2000	DE 20015197 U1	26-10-2000
US 4196380	A	01-04-1980	CH 629008 A5	31-03-1982
			DE 2754497 A1	15-06-1978
			FR 2373821 A1	07-07-1978
			GB 1591287 A	17-06-1981
			JP 53077980 A	10-07-1978
			SE 7613820 A	10-06-1978
DE 977732	C	12-12-1968	NONE	
US 5300918	A	05-04-1994	DE 4207064 A1	16-09-1993
			AT 137012 T	15-05-1996
			DE 59302221 D1	23-05-1996
			EP 0560143 A1	15-09-1993